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A COMPARISON OF MILLING VALUE OF SPELT WHEAT AND COMMON WHEAT GRAIN GROWN IN ORGANIC FARMING SYSTEM

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Key words: spelt wheat, common wheat, kernel quality, milling properties, organic farming.

Abstract

The objective of the studies was to compare the milling properties of spelt wheat and winter and spring common wheat kernels. The studies were carried out with winter spelt wheat cv. Schwabenkorn and Franckenkorn and with common wheat: winter variety cv. Korweta and spring variety cv. Bombona. Spelt wheat and common wheat were grown in organic farming systems. The evaluation of kernel milling value was performed based on the physical and chemical kernel characteristics and with a trial laboratory milling. Thousand kernel weight, test weight, vitreousness, hardness and content of total ash in the kernels and flour were determined. The milling efficiency factor *K*, ash number and specific energy for kernel comminution (E_r) were calculated. The granulometric composition of middlings (milling product) was also determined with laser diffraction.

It was shown that spelt wheat kernels had lower milling parameters than common wheat grain. Out of the tested grain samples, spelt wheat – in comparison with common wheat – had a more floury structure of the endosperm and significantly higher ash content in kernels. Less flour was obtained from spelt wheat than from common wheat. The highest volume of flour was produced from spring wheat cv. Bombona. Specific energy input for milling of spelt wheat kernels was significantly lower in comparison with common wheat. The milling of common wheat cv. Bombona consumed the highest amount of energy; it resulted from higher hardness of kernels. The average particle size of the products obtained by common wheat milling was positively correlated with vitreousness of grain.

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PORÓWNANIE WARTOŚCI PRZEMIAŁOWEJ ZIARNA ORKISZU I PSZENICY ZWYCZAJNEJ UPRAWIANYCH W SYSTEMIE ROLNICTWA EKOLOGICZNEGO

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Słowa kluczowe: pszenica orkisz, pszenica zwyczajna, jakość ziarna, właściwości przemiałowe, rolnictwo ekologiczne.

Abstract

Celem badań było porównanie właściwości przemiałowych ziarna pszenicy orkiszu z ziarnem ozimej i jarej pszenicy zwyczajnej. Materiał badawczy stanowiło ziarno orkiszu ozimego odmian Schwabenkorn i Franckenkorn oraz pszenicy zwyczajnej: formy ozimej odmiany Korweta i jarej odmiany Bombona. Orkisz oraz pszenica zwyczajna uprawiane były w systemie rolnictwa ekologicznego. Wartość przemiałową ziarna oceniono na podstawie jego cech fizykochemicznych oraz wykonując próbny przemiał laboratoryjny. Oznaczono masę tysiąca ziaren, gęstość w stanie usypowym, szklistość, twardość oraz zawartość popiołu całkowitego w ziarnie i w uzyskanych po przemiale mąkach. Obliczono współczynnik efektywności przemiału *K*, liczbę popiołową oraz określono jednostkową energię rozdrabniania ziarna (E_r). Wyznaczono także skład granulometryczny śruty metodą dyfrakcji laserowej. Wykazano, że ziarno orkiszu cechowało się gorszymi właściwościami przemiałowymi niż ziarno ozimej pszenicy zwyczajnej. Spośród badanych prób ziarna, orkisz w porównaniu z pszenicą zwyczajną cechował się bardziej mączystą strukturą bielma oraz istotnie większą zawartością popiołu w ziarnie. Z ziarna orkiszu uzyskano mniej mąki niż z pszenicy zwyczajnej. Największą ilość mąki uzyskano z pszenicy jarej odmiany Bombona. Jednostkowe nakłady energetyczne na przemiał ziarna orkiszu były znacząco mniejsze niż na przemiał ziarna pszenicy zwyczajnej. Najwięcej energii wymagał przemiał ziarna pszenicy zwyczajnej odmiany Bombona. Wynikało to z większej twardości ziarna. Średni rozmiar cząstek produktów przemiału pszenicy zwyczajnej był dodatnio skorelowany ze szklistością ziarna.

Introduction

Spelt wheat (*Triticum spelta L.*) is one of the oldest species of wheat. In recent years there has been a growing interest in spelt wheat, which is mainly utilized in the milling and cereal industry. This interest may result from the nutritional values of spelt wheat. It is thought (BONAFACCIA et al. 2000, SULEWSKA et al. 2008, BIEL et al. 2010) that spelt wheat grain has a more beneficial chemical composition and better nutritional value in comparison with common wheat grain. It contains more protein with higher nutritional value, lipids, mineral compounds, vitamins and dietary fiber (MARCONI et al. 1999, BONAFACCIA et al. 2000, ABEL-AAL, HUCL 2002, RUIBAL-MENDIETA et al.

2005). Spelt wheat is a very valuable crop for organic agriculture, since it has retained its native characteristics and it is therefore well suited for organic methods of growing. It should be emphasized that the advantage in yielding of common wheat over spelt wheat decreases in sites of less favourable growing conditions (CASTAGNA et al. 1996, LACKO-BARTOSOVA, OTEPKA 2001).

Technological characteristics of spelt wheat, similar to common wheat, are determined based on such parameters as kernel milling value and baking flour value. Physical and chemical parameters and a milling laboratory test constitute the kernel milling value (DZIKI, LASKOWSKI 2005). Kernel parameters influence the milling and quality of flour. According to POSNER (2003), the quality of flour depends in app. 75% on the quality of raw material and in app. 25% on milling technology. The quality of flour is important in the subsequent stages of processing and exerts an impact on the properties of final products such as bread, pasta, cakes, cookies, and other bakery products (KONIK et al. 1992, STEVE et al. 1995, ZHANG et al. 2005).

Since the area of spelt wheat growing is expanding in Poland and around the world, it becomes necessary to evaluate its grain for milling value. Improvement of milling properties is an important aspect of common wheat and spelt wheat breeding programs. It is of particular importance in organic production in which there is a limited capacity for influencing grain quality due to elimination of fertilization with synthetic nitrogen and of synthetic crop protection agents. Therefore, the objective of the studies was to compare the milling properties of spelt wheat and common (spring and winter) wheat grown in organic system.

Materials and Methods

The study was carried out with winter spelt wheat cv. Schwabenkorn and Franckenkorn and common wheat: winter variety cv. Korweta and spring variety cv. Bombona, all grown in organic system. The samples of grain originated from 3 certified organic farms located in Budziszewo (heavy soil), Zgniłobłoty (medium soil) and Łęgno (medium soil) from the harvests collected in 2010. The samples of spelt wheat, each 10 kg, were hulled on a laboratory device LD 180 ST 4 (WINTERSTEIGER). The evaluation of milling value was carried out based on the physical and chemical properties of grain and a trial laboratory milling in a Quadrumat Junior mill (Brabender) equipped with a cylindrical sifter wrapped with a 70GG sieve (PE 236 μm). The humidity of kernels (PN-EN ISO 712: 2009) was determined and then for 24 hours before milling grain was re-moisturized to 14.5% by adding an appropriate volume of water. Thousand kernel weight (PN-EN ISO 520:2011), test weight (otherwise:

bulk density of grains) (PN-EN ISO 7971-3: 2010), kernel vitreousness (PN70/R-74008) and total ash content in grain and in flour (PN-EN ISO 2171:2010) were also determined. Particle size index (PSI) was calculated as the mass percentage of particles smaller than 75 μm in the milled products in accordance with AACC 55-30:2000 method,

$$PSI = \frac{m_p}{m_0} \cdot 100\% \tag{1}$$

where:

m_p – weight of sieved material (d < 0.075 mm) [g],

m_0 – weight of collected sample [g].

The milling efficiency factor K (the quotient of flour yield to the content of ash in flour) and the ash number (the quotient of ash content in flour to the flour yield multiplied by 100000) were also calculated. The results were compared with a 5-degree scale of milling value developed in the Central Laboratory for Cereal Processing and Storage in Warsaw for the Quadrumat Junior mill (SITKOWSKI 2011).

The volume of energy used for comminution was determined based on the measurement of energy supplied to the mill. Comminution time was measured with a stop-watch to an accuracy of ± 0.1 s. The real power utilized by the mill was also measured. The energy necessary for putting the elements of the comminuter into motion was calculated as the quotient of real power of idle running to comminution time. The operation of comminuting a given grain sample was determined assuming that the total energy consumed by the comminuter equaled the sum of energy for comminuting and energy for putting its elements into motion. The specific energy for comminuting E_r (kJ kg^{-1}) was determined with the following equation,

$$E_r = \frac{E_c - E_s}{m} \tag{2}$$

where:

E_c – total energy consumed by feed mill [kJ],

E_s – energy of idle running ($E_s = P_s \cdot t_r$) [kJ],

m – weight of comminuted sample [kg].

The granulometric composition of middlings (milled grain, the milling product) was also determined with laser diffraction analysis (LDA) on a Malvern Mastersizer 2000 analyzer. The results of the measurement were the mean from three subsequent repetitions. The analysis of granulometric composition of middlings (milled grain) allowed us to determine the average size of particle according to the following formula (VELU et al. 2006):

$$d_p = \sum_{i=1}^{n} \varphi_i d_i \tag{3}$$

where:
φ_i – proportion of size fraction i in the tested sample [kg kg^{-1}],
d_i – average size of i fraction particles [μm],
n – number of size fractions.

The sizes of particles corresponding to the level of sieving at 10%, 50% and 90% (d(0.1), d(0.5) and d(0.9), respectively) were determined with the cumulative function of the granule size composition of milled product. The relative width of distribution (SPAN) was calculated with the following formula:

$$\text{SPAN} = \frac{d(0.09) - d(0.01)}{d(0.5)} \tag{4}$$

The results were statistically analyzed. The analysis of variance was performed with STATISTICA® for Windows v. 10 (StatSoft Inc.). The significance of differences between the means was determined with Tukey test. The statistical hypotheses were tested at $\alpha = 0.05$.

Results and Discussion

The results of evaluation of quality parameters in spelt wheat and common wheat grain are presented in Table 1. The tested samples of grain were differentiated in the majority of indirect indices of milling value. The test weight of winter wheat variety Korweta was highest (71.9 kg hl^{-1}) and significantly different from the test weight of tested spelt wheat varieties. The variety Bombona of spring wheat significantly differed in its test weight from the variety Schwabenkorn of spelt wheat. Thousand kernel weight (TKW) is one of the basic indices of sowing potential and commodity quality of cereals; it indicates the ripeness of grain. TKW for the tested spelt wheat grain ranged from 39.0 to 43.5 g and was significantly higher than TKW for common wheat. It is thought (POSNER 2003) that thousand kernel weight corrected to the constant level of humidity is a good indicator of milling properties, including the milling yield of flour. The main factors that influence the behavior of grain during milling are vitreousness and hardness of kernels (GREFFEUILLE et al. 2007a, GREFFEUILLE et al. 2007b, DZIKI et al. 2011). Among the tested samples, only the kernels of winter wheat variety Korweta had a vitreous structure of the endosperm. The grain of spelt wheat and spring wheat cv. Bombona was floury. The kernels of spelt wheat were less vitreous than common wheat. The hardness of the tested kernels expressed with PSI ranged from 30% for spring wheat cv. Bombona to 64% for winter wheat cv. Korweta. The kernels of Bombona variety were classified as soft, whereas the grain of spelt wheat and common wheat cv. Korweta was categorized as extra soft.

Table 1

Results of the evaluation of physical and chemical parameters of common wheat and spelt wheat kernels

Trait	Common wheat		Spelt wheat	
	Korweta	Bombona	Franckenkorn	Schwabenkorn
Test weight [kg hl^{-1}]	71.9^c	67.3^a	67.2^a	69.6^b
Thousand kernel weight [g]	36.5^a	36.7^a	39.0^b	43.5^c
Vitreousness [%]	60^c	32^b	6^a	9^a
PSI [%]	64^a	30^b	62^a	59^a
Ash in grain [%]	1.94^c	1.75^b	2.07^a	2.09^a

Explanatory notes:
a, b, c – differences of values in letter (for the given variety) marked with the same letters are insignificant at α = 0,05

The content of ash in the tested samples of spelt wheat was relatively high: 2.07% for the Franckenkorn variety and 2.09% for the Schwabenkorn variety. A comparable concentration of ash in spelt wheat kernels was reported by CAPOUCHOVA (2001) and MARCONI et al. (2002). Similar to the studies by other authors (KRAWCZYK et al. 2008a, CACAK-PIETRZAK, GONDEK 2010), spelt wheat grain had a higher ash content than common wheat kernels.

Milling yield of flour is used for a direct evaluation of the milling properties of common wheat grain. The yield of flour obtained from spelt wheat grain was significantly lower than the yield of flour produced by milling of common wheat kernels (Table 2). The highest flour yield (69.1%) was recorded for spring wheat cv. Bombona. Numerous studies (ABDEL-AAL et al. 1997, CAPOUCHOVÁ 2001, MARCONI et al. 2002, KRAWCZYK et al. 2008b) have indicated that milling of spelt wheat produces less flour in comparison with common wheat; it indicates its worse milling parameters. This was confirmed in our studies. It is thought (POSNER 2003) that flour yielding is positively correlated with thousand kernel weight. Our studies revealed a reverse correlation. Together with the increase in thousand kernel weight, the yielding of flour decreased (r = -0.609) (Table 3). According to the data found in the literature (DOBRASZCZYK 1994, HADDAD et al. 1999, TURNBULL, RAHMAN 2002), higher yielding of flour is associated with higher vitreousness of the endosperm and hardness of kernels. It was evidenced by our studies with the correlation coefficients between the volume of flour and the structure of wheat endosperm and between the volume of flour and PSI (Table 3).

Table 2

Results of the evaluation of milling value of common wheat and spelt wheat grain

Trait	Common wheat		Spelt wheat	
	Korweta	Bombona	Franckenkorn	Schwabenkorn
Milling yield [%]	62.5[c]	69.1d	52.9[a]	57.2[b]
Total ash content in flour [%]	0.57[ab]	0.66[b]	0.52[a]	0.55[ab]
Milling efficiency factor K [–]	111[b]	105[a]	101[a]	105[a]
Ash number [–]	904[a]	976[a]	991[a]	958[a]
Energy for comminuting [kJ kg^{-1}]	55[b]	65[c]	36[a]	36[a]
SPAN	11.482[c]	2.426[b]	9.922[a]	9.207[a]
Average particle size of milling product d_{Sr} [μm]	129.262[a]	230.505[b]	128.764[a]	141.321[a]
Assessment of milling value	medium – sufficient	low	low	low

Explanatory notes as in Table 1.

Table 3

Statistically significant values of linear correlation coefficients between the physical and chemical parameters of kernels and the milling parameters

Trait	Milling yield	Total ash content in flour	Milling efficiency factor	Ash number	Energy for comminuting	Average particle size of middlings
Test weight			0.816			
Thousand kernel weight	–0.609	0.729			–0.789	
Ash in grain	–0.922	–0.819			–0.949	
Vitreousness	0.848	–0.894	0.896		0.772	0.920
PSI	–0.777	–0.866			–0.708	–0.993

Ash content in flour is an important index in the evaluation of milling properties. Kernels with low ash content, particularly in the endosperm, are desirable raw materials for the cereal and milling industry. The ash content in flour ranged from 0.52% (spelt wheat cv. Franckenkorn) to 0.66% (common wheat cv. Bombona). A statistically significant difference was detected only between the ash content in flour produced from common wheat cv. Bombona and flour produced from spelt wheat cv. Franckenkorn. Contrary to the results of other studies (CACAK-PIETRZAK et al. 2005, SOBCZYK et al. 2009, CACAK-PIETRZAK, GONDEK 2010), the content of ash in flour was negatively correlated with the content of ash in grain (r = –0.819).

Most of the mineral components in grain are concentrated in the layer adherent to the seed cover and within the seed cover. High ash content in wheat grain is reflected in a higher concentration of mineral compounds in the endosperm. Consequently, this results in an increase in the ash content in produced flour (POSNER 2009). However, according to SPIEGEL and KLABUNDE (1995), correlations between the ash content in grain and in the endosperm and the ash content in flour are related to its yielding. If the yielding is below 72%, only the content of ash in the endosperm exerts an impact on the content of ash in flour. If the yielding increases to 80%, the content of ash in the whole kernel influences the ash content in flour.

In order to compare the milling properties of common wheat and spelt wheat, the milling efficiency coefficient K was calculated; it includes flour yield in relation to its ash content. The values of milling efficiency coefficient K ranged from 101 to 111 (Table 2). The highest milling efficiency was detected for the kernels of common wheat cv. Korweta; this result combined with the ash number (904) classifies it as a grain with moderately satisfactory milling properties. Both spelt wheat and spring wheat cv. Bombona were categorized as poor. The comminution of common wheat kernels required higher energy input than that necessary for the comminution of spelt wheat grain. Significant correlations were found between the vitreousness of common wheat and the energy requirement for comminution (r = 0.772). Spelt wheat that has a floury structure of the endosperm did not require such high energy input as more vitreous kernels of common wheat. According to PUJOL et al. (2000), differences in the consumption of energy for comminuting common wheat varieties with soft and hard endosperm may amount to 100%. CACAK-PIETRZAK et al. (2009) and CACAK-PIETRZAK, GONDEK (2010) claim that vitreous kernels are more resistant and require higher energy input for comminution. The reason lies in the structure of the kernel. In vitreous kernels, starch grains are deeply embedded in the protein matrix in contrast with the structure of floury kernel which has a loose endosperm structure.

Granule size composition of milled products (flour, crushed cereal meal) is an important parameter of milling value, since it influences further stages of processing. It determines the properties of flour during dough-making and baking. It also exerts an impact on the water absorption capacity of flour (Popper et al. 2006). According to Park et al. (2006), the size of flour particles is one of two most important parameters (after protein content and parameters of flour quality) which influence the porosity of wheat bread. Granule size composition is associated with the volume content of individual components of comminuted kernels that are finally found in different size fractions of milled grain. Milled products are composed of a number of fractions. The multimodal nature of granule size composition of milled cereals grain has also been shown by other authors (Devaux et al. 1998).

All tested milled products were highly poly-dispersive. Based on the curves of granule size composition, five fractions are identified (Figure 1) that constitute milled products. The milling of spelt wheat yielded five fractions, whereas the milled products from common wheat cv. Bombona did not contain 1 μm and 100 μm fractions. The fraction composition of milled products obtained from common wheat cv. Korweta approximated that of spelt wheat, but the proportion of 100 μm fraction was significantly smaller (app. 75% of this fraction in comparison with spelt wheat). The granule size composition of milled products from common wheat cv. Korweta included the particles of 200 μm as the basic fraction and the traces of 30 and 4 μm fractions. Two fractions, i.e. 30 and 600 μm, were predominant in the milled products obtained from spelt wheat and common wheat cv. Korweta. The relative width of particle size distribution (SPAN) ranged from app. 2.5 for common wheat cv. Bombona to app. 11.5 for Korweta variety (Table 2). The statistical analysis did not reveal any significant differences between the SPAN determined for the tested spelt wheat varieties; this value amounted on average to 9.5.

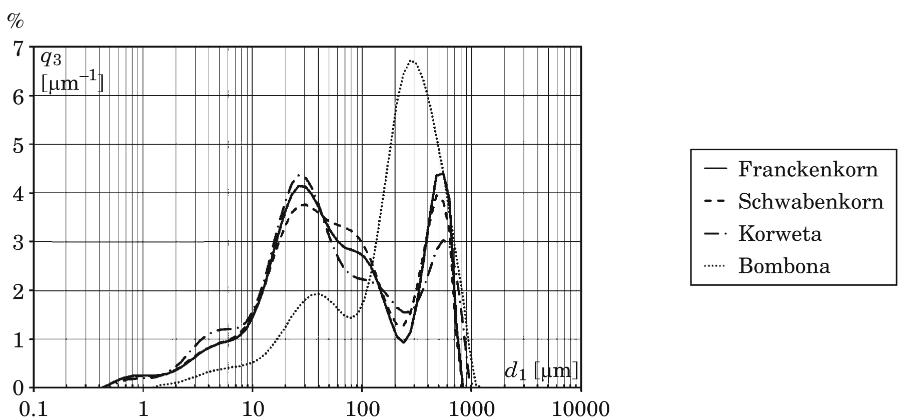

Fig. 1 Granulometric composition of middlings obtained from common wheat and spelt wheat

The average particle size ranged between 130 to 230 μm. Significant differences were found between the average particle size of the milled product obtained from common wheat cv. Bombona and the other tested common wheat varieties. The statistical analysis revealed a high correlation between the average particle size of the milled product and the vitreousness of kernels (Table 3). A significant negative correlation between PSI and the average particle size of milled product obtained from the tested material is explained with a mathematical relation linking these indices.

Conclusions

1. Spelt wheat grain had worse milling parameters than winter wheat kernels.
2. The specific work utilized to comminute spelt wheat grain is significantly lower in comparison with common wheat grain.
3. The average particle size of the milled products obtained from common wheat varieties was positively correlated with the vitreousness of kernels.

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